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Operative vs. nonoperative treatment for Mason type 2 radial head fractures: a randomized controlled trial

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Background: The optimal treatment of isolated displaced partial articular radial head fractures remains controversial. The aim of this randomized controlled trial was to compare the functional outcome of operative treatment with nonoperative treatment in adults with an isolated Mason type 2 radial head fractures.

Methods: In this multicenter randomized controlled trial, patients from 18 years of age with an isolated partial articular fracture of the radial head were randomly assigned to operative treatment by means of open reduction and screw fixation or nonoperative treatment with a pressure bandage. The primary outcome was function assessed with the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire. Questionnaires and clinical follow-up was conducted at admission and at 3, 6, and 12 months.

Results: In total, 45 patients were randomized, 23 patients to open reduction and screw fixation and 22 patients to nonoperative treatment with a pressure bandage. At 3, 6, and 12 months, patients treated operatively had similar functional outcomes compared to patients treated nonoperatively (DASH score at 12 months: 0.0 [0.0-4.2] vs. 1.7 [0.0-8.5]; $P = .076$).

Conclusions: Nonoperatively treated adults with an isolated Mason type 2 radial head fracture have similar functional results after 1 year compared with operatively treated patients. In addition, complication rates were low for both operative and nonoperative treatment.

Level of evidence: Level II; Randomized Controlled Trial; Treatment Study

Keywords: Radial head; fracture; Mason type 2; screw fixation; function; DASH

Institutional approval was obtained from the Medical Ethics Review Committee METC Brabant (nr. 1169), and the boards of directors of all participating centers.

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Radial head fractures of the elbow are common fractures, with an incidence of 2.5-2.9 per 10,000 persons each year.[17] The Mason classification, which was introduced in 1954 and later modified by Broberg and Morrey in 1986 by adding a metric definition of displacement, is the most often used classification.[3,21] Mason type 1 fractures, which include a fissure or marginal sector fracture without displacement, can be treated nonoperatively with early mobilization.[5,11,9,28] It is also known that patients with complete articular fractures involving the whole radial head, that is, Mason type 3 fractures, benefit from surgical treatment. These fractures should be treated either by open reduction and internal fixation or by arthroplasty in case of comminuted unreconstructable fractures.[5,13,24,25] Mason type 2 fractures comprise displaced partial articular radial head fractures. For so-called isolated Mason type 2 fractures (ie, not associated with other fractures or ligament injuries), treatment remains controversial. Good short- and long-term results have been reported for both nonoperatively treated and operatively treated radial head fractures.[2,10,19,20,22,29] However, a meta-analysis on the optimal treatment of isolated displaced Mason type 2 radial head fractures found insufficient evidence to guide treatment, mainly because of a low level of evidence.[16]

Hence, the aim of this randomized controlled trial was to compare the functional outcome of operative treatment with nonoperative treatment in adults with a Mason type 2 radial head fracture.

Materials and methods

Study design and eligibility criteria

The RAMBO (Radial Head–Amsterdam–Amphia–Boston–Others) trial was a multicenter prospective randomized controlled trial, conducted at 7 hospitals in the Netherlands from September 2012 to February 2017. Institutional approval was obtained from the Ethics Committee and Institutional Review Board, and the boards of directors of all participating centers. All patients provided written informed consent before randomization. The trial protocol has previously been published.[4]

All adult patients with an isolated Mason type 2 radial head fracture were eligible to participate. Inclusion criteria included all adults with an isolated partial articular fracture of the radial head that comprised at least one-third of the articular surface and had at least 2 mm of articular step-off but less than 2 mm of gap between the fragments, as measured on an anteroposterior and lateral radiograph (Fig. 1). This definition is referred to as the modified Mason classification and is widely used in treatment decisions. Fractures were classified on lateral and posteroanterior radiographs by an experienced radiologist or orthopedic trauma surgeon. An additional computed tomographic scan with axial, coronal, and sagittal reconstructions was also recommended to verify if fractures were correctly classified and included.

Exclusion criteria were polytraumatized patients (ie, an injury severity score >15), radial head fractures as part of an elbow dislocation, other fractures or dislocations of the ipsilateral or the contralateral arm, open or pathologic fractures, previous ipsilateral olecranon/distal humerus/radial head fractures, pre-existent neurologic disorders affecting the upper extremity, and patients unfit for general anesthesia and/or operative management.

Randomization and blinding

Patients were randomized in a 1:1 ratio to operative treatment by means of open reduction and screw fixation or nonoperative treatment with a pressure bandage. Randomization was performed using a secured web-based computerized randomization procedure with random block sizes.

Randomization was stratified by age, 18-49 and $\geq$50 years. Because the assignment involved a surgical procedure, neither participants nor treating physicians were blinded to the treatment allocation.

Interventions

A detailed description of the interventions has previously been published.[4] Open reduction and screw fixation was performed by a certified (orthopedic) trauma surgeon or by a surgical resident under the supervision of a certified (orthopedic) trauma surgeon. The extensor digitorum communis splitting approach or the Kocher approach was used in all patients. Fractures were either surgically fixed with headless compression screws (Fig. 2, *a*) or with cannulated lag screws (Fig. 2, *b*). In the latter, the screw heads were countersunk just below the level of the articular cartilage. The number and type of screws used was subject to the preference of the treating surgeon. Participants randomized to nonoperative treatment received a pressure bandage for a maximum of 72 hours and a sling for comfort.

A leaflet with identical instructions, including flexion and extension of the elbow, and pronation and supination, were given to both operatively and nonoperatively treated patients. Patients treated operatively were instructed to use the elbow immediately after the surgery as pain allowed. Patients treated nonoperatively were allowed to start using their elbow immediately after a resting period of 48 hours. Rehabilitation with a physiotherapist was at the discretion of the patient and treating physician.

Outcomes

Patients were assessed at the emergency department or outpatient clinic. Questionnaires and clinical assessment were administered at admission and at 3, 6, and 12 months. Clinical assessment was performed by an independent examiner, who was not blinded to the allocated treatment because the scars on the elbow in the operative group could easily be observed.

The primary outcome was the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire score at 12 months of follow-up. The DASH questionnaire is a 30-item, self-report questionnaire designed to measure physical function and symptoms in patients with any or several musculoskeletal disorders of the upper limb. The DASH score ranges from 0-100, with 0 indicating no disability.[14] Secondary outcomes were the functional outcome measured with the Oxford Elbow Score (OES), the Mayo Elbow Performance Score (MEPS), range of motion, pain scores

Figure 1 Partial articular radial head fracture, Mason type 2 according to the modified Mason classification.

measured with the visual analog scale (VAS), the number of patients who practiced with a physiotherapist, and complications. The OES reflects both function and pain following elbow surgery. The OES ranges from 0-48, with lower scores representing greater severity.[8] The MEPS is an instrument used to test the limitations, caused by pathology, of the elbow during activities of daily living. The MEPS is based on 4 domains: pain, range of motion, stability, and elbow function. A total score between 90 and the maximum 100 points is considered excellent; 75-89 is good; 60-74 is fair; and less than 60 points is poor.[7]

Range of motion was measured with a handheld goniometer and included flexion and extension of the elbow, and pronation and supination of the forearm in 90° of flexion. In addition, the presence of crepitus in the injured joint was recorded. A complication was defined as any adverse event for which any additional treatment was required.

Statistical analysis

With an α equal to 0.05%, a sample size of 31 patients in every arm was required to provide 85% power to detect a minimal clinically important difference of 17 points on the DASH score.[26] To correct for the loss to follow-up, a total of 78 patients had to be included.

Because of slow recruitment and a high number of crossovers from the operative group to the nonoperative group, a preliminary 1-sided interim analysis was performed on the DASH score at 12 months. Five patients who were randomized for surgery insisted on nonoperative treatment because of minor complaints just before the scheduled surgery. This analysis showed that the DASH score in the nonoperative group at 12 months was comparable, or even better, to the normative value for the DASH score.[1,15] Therefore, with approval of the AO Foundation, the decision was made to prematurely terminate the trial after inclusion of 45 patients.

All analyses were performed according to the intention-to-treat principle. To compare the baseline characteristics between both groups, a Mann-Whitney *U* test was used for age, and a χ^2 test was applied for the analysis of sex, fracture side, smoking status, and the presence of diabetes mellitus. To test for differences between the groups in the DASH and OES scores, and MEPS at the follow-up time points, an analysis of covariance corrected for age was performed. A linear mixed model was applied to range of motion and the VAS pain scores. The best covariance structure for each linear mixed model was determined using the smallest Akaike information criterion. In both the analysis of covariance and the linear mixed model, the data were ranked by follow-up time point if they were non-normally distributed.[6] To verify the normality of the ranked data, the histograms of the residuals were visually inspected. All outcome measures were corrected for age, as this was a stratification factor in the design of the study.[18] Single imputation was used to impute missing data, applying predictive mean matching, with treatment and the other follow-up measurements as predictors. Additionally, a per-protocol analysis was performed.

Two-sided *P* values of $<.05$ were considered statistically significant. All analyses were performed with SPSS software, version 24 (IBM, Armonk, NY, USA). This trial was registered with the Dutch Trial Register (NTR3413).

Results

A total of 49 patients were included. Four patients randomized to operative treatment withdrew informed consent after randomization (Fig. 3). Twenty-three patients were randomly assigned to open reduction and screw fixation and 22 patients to nonoperative treatment with a pressure bandage. The median age was 50 years (interquartile range 45.5-58.0) and slightly more than one-half of patients was female. Baseline characteristics were well balanced (Table I). At admission, DASH, OES, and MEPS scores were comparable between both groups (Table II). There were no differences in range of motion at admission, except for extension of the elbow, which was better in the nonoperative group compared with the operative group (median extension deficit 30° [24°-40°] vs. 24° [14°-30°], $P = .036$; Table II). Open reduction and screw fixation was performed at a median of 8 days (interquartile range 6-11) following trauma.

Figure 2 Partial articular radial head fracture fixed (**a**) with headless compression screws or (**b**) with cannulated lag screws.

Twenty-two patients in the operative group and 19 patients in the nonoperative group received a computed tomographic scan. There were 6 crossovers; 5 patients randomized to operative treatment underwent nonoperative treatment at own request because of minor complaints just before the scheduled surgery, 1 patient randomized to nonoperative treatment underwent operative treatment because of a loose body in the elbow joint at the preoperative computed tomographic scan, as was suspected on the initial radiograph (Fig. 4). Despite the clinical lack of block to forearm rotation, the treating surgeon felt operative treatment was inevitable because of the intra-articular nature of the fragment.

At 3, 6, and 12 months, patients treated operatively had similar functional outcomes, measured with the DASH, OES, and MEPS scores, compared with patients treated nonoperatively (Table III). At 12 months, the proportion of patients scoring excellent or good on the MEPS was 96% in the operative group and 91% in the nonoperative group.

Range of motion and VAS pain scores improved during follow-up, both in the operative and nonoperative group.

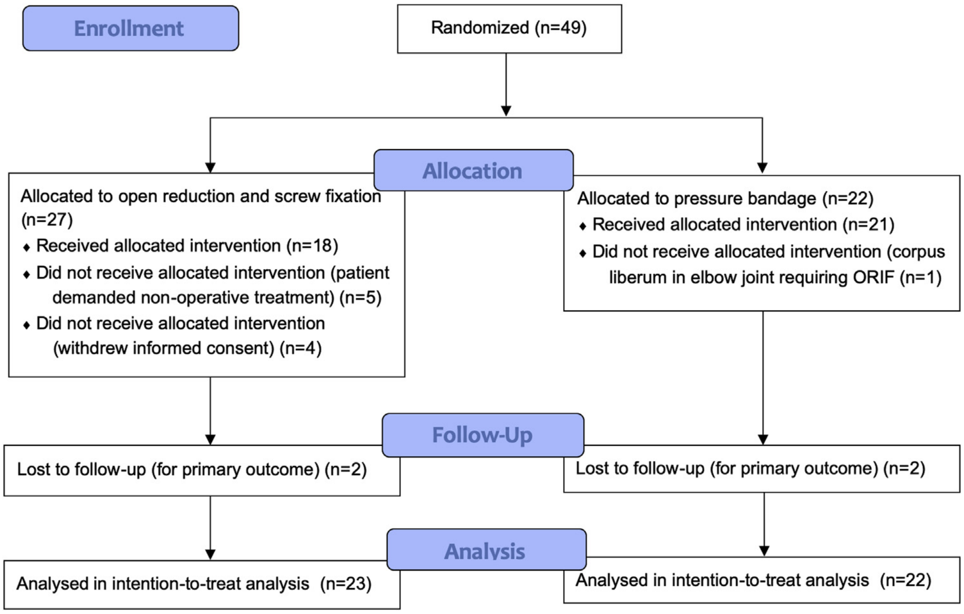

Figure 3 CONSORT (Consolidated Standards of Reporting Trials) flow diagram of the RAMBO trial (Radial Head–Amsterdam–Amphia–Boston–Others).

Differences between both groups were not significant (Table IV).

At 3 months, 12 patients in the operative group and 13 patients in the nonoperative group practiced with a physiotherapist. At 6 months, the number of patients practicing with a physiotherapist was 6 and 4, and at 12 months 7 and 6 patients, respectively.

Painless crepitus in the elbow joint during forearm pronation and supination at 12 months was present in 6 patients—3 patients in the operative group and 3 patients in the nonoperative group.

One patient in the operative group had a superficial wound infection for which oral antibiotics were administered. At the 6-month follow-up, 1 patient in the nonoperative group received a plaster cast for 4 weeks because of complaints of the affected elbow, most likely caused by overuse. After these 4 weeks of treatment, the complaints resolved. In addition, 1 patient in the nonoperative group who underwent open reduction and screw fixation because of a loose body in the elbow joint underwent removal of 2 of 3 screws at 3 months. No patients in the operative group underwent implant removal.

In an additional per protocol analysis, DASH, OES, and MEPS scores were not significantly different between the 2 groups (Supplemental Appendix S1).

Discussion

This multicenter randomized trial showed that nonoperatively treated patients with an isolated Mason type 2 radial head fracture have similar results as operatively treated patients, with excellent functional outcomes at 12 months of follow-up. In addition, complication rates were low for both operative and nonoperative treatment.

Traditionally, restoration of the articular surface is an important factor in the prevention of post-traumatic osteoarthritis.[5] Although the follow-up of this study was too short to determine osteoarthritis, previous studies have reported on the long-term results of nonoperatively and operatively treated Mason type 2 radial head fractures. In a retrospective study in 2006, Lindenhovius and colleagues found slight degenerative changes in 2 of 16 patients with an operatively treated Mason type 2 radial head fracture with an average of follow-up of 22 years.[20] In contrast, Akesson et al[2] in a retrospective study of 49 patients with a nonoperatively treated Mason type 2 radial head fracture found that degenerative changes were more often present in the formerly injured elbow (82%) compared with the uninjured elbow (21%). However, these degenerative changes remained asymptomatic because subjective functional outcomes were good; 82% of patients had no elbow complaints. Another retrospective study[29] compared 30 nonoperatively and 30 operatively treated patients with an isolated partial radial head fracture with 2-5 mm displacement. They found 1 patient in the nonoperative group with degenerative changes and 8 patients in the operative group. Moreover, functional outcomes measured with the MEPS were significantly better in the nonoperative group compared with the operative group (mean 93, 95% confidence interval [CI] 89-97, vs. 86, 95% CI 80-90; $P = .01$). However, no differences between both groups in QuickDASH and Patient Rated Elbow Evaluation scores were found.

Table I Baseline demographics of included patients

	Total (N = 45)	Operative group (n = 23)	Nonoperative group (n = 22)	*P* value
Age, yr, median (IQR)	50 (45.5-58.0)	50.0 (46.0-59.0)	50.5 (43.3-54.3)	.554
Sex, n (%)				.463
Female	25 (56)	14 (61)	11 (50)	
Male	20 (44)	9 (39)	11 (50)	
Fracture to dominant side, n (%)	24 (60)	10 (56)	14 (64)	.604
Diabetes mellitus, n (%)				.343
Yes	4 (10)	1 (5)	3 (15)	
No	37 (90)	20 (95)	17 (85)	
Smoking, n (%)				.414
Yes	7 (16)	5 (22)	2 (9)	
No	38 (84)	18 (78)	20 (91)	

IQR, interquartile range.

Table II Functional outcomes and VAS pain score at admission

	Operative group, median (IQR)	Nonoperative group, median (IQR)	*P* value
DASH	65.8 (42.5-82.5)	68.8 (52.5-80.8)	.873
OES	13.0 (11.0-18.0)	11.0 (8.0-14.0)	.163
MEPS	60.0 (35.0-65.0)	55.0 (33.8-65.0)	.446
Flexion, degrees	106 (90-120)	120 (98-126)	.164
Extension deficit, degrees	30 (24-40)	24 (14-30)	**.036**
Pronation, degrees	75 (50-85)	75 (51-86)	.953
Supination, degrees	62 (40-85)	60 (44-73)	.643
VAS	7 (4-9)	6 (5-8)	.817

VAS, visual analog scale; *DASH*, Disabilities of the Arm, Shoulder, and Hand; *OES*, Oxford Elbow Score; *MEPS*, Mayo Elbow Performance Score; *IQR*, interquartile range.
All reported outcome measures are corrected for age, except for VAS pain score. Statistically significant values are presented in bold.

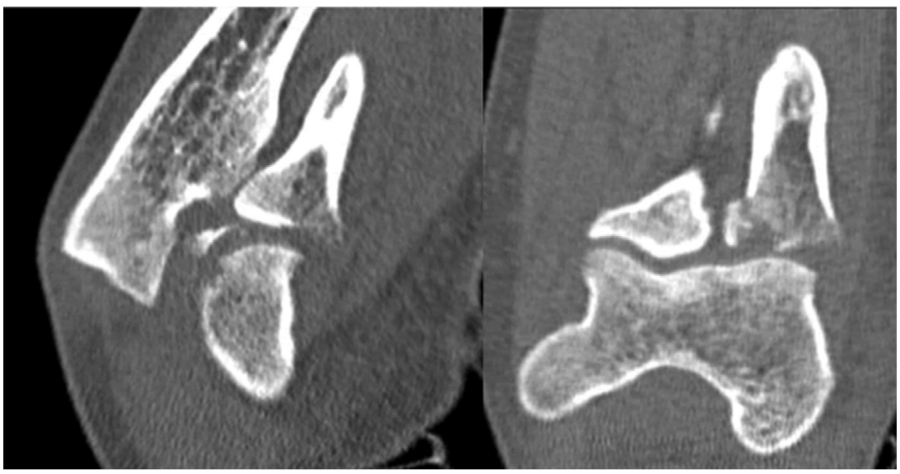

Figure 4 Loose body found in the elbow joint at the preoperative computed tomographic scan.

This study only included isolated Mason type 2 fractures, which can be considered stable injuries. These types of fractures are typically impacted into a stable position with cortical contact and an intact annular ligament. These fractures should be distinguished from unstable radial head fractures as a part of complex elbow fracture dislocations.[20]

Table III Patient-reported outcomes

	Operative group, median (IQR)	Nonoperative group, median (IQR)	*P* value
3 mo			
DASH	14.2 (1.7-22.5)	12.1 (4.6-19.4)	.966
OES	40.0 (30.0-46.0)	38.5 (32.8-43.3)	.575
MEPS	85.0 (70.0-100.0)	92.5 (73.8-100.0)	.734
6 mo			
DASH	3.3 (0.0-6.7)	5.4 (0.6-30.4)	.110
OES	46.0 (43.0-48.0)	44.0 (35.3-47.0)	.092
MEPS	100.0 (95.0-100.0)	100.0 (85.0-100.0)	.798
12 mo			
DASH	0.0 (0.0-4.2)	1.7 (0.0-8.5)	.076
OES	48.0 (43.0-48.0)	46.0 (41.0-48.0)	.114
MEPS	100.0 (100.0-100.0)	100.0 (85.0-100.0)	.282

DASH, Disabilities of the Arm, Shoulder, and Hand; *OES*, Oxford Elbow Score; *MEPS*, Mayo Elbow Performance Score; *IQR*, interquartile range.
All reported outcome measures are corrected for age.

Table IV Clinical outcomes

	3 mo		6 mo		12 mo		*P* value
	Operative group, median (IQR)	Nonoperative group, median (IQR)	Operative group, median (IQR)	Nonoperative group, median (IQR)	Operative group, median (IQR)	Nonoperative group, median (IQR)	
Flexion, degrees	135 (130-140)	133 (129-140)	140 (132-140)	140 (137-143)	140 (134-144)	140 (134-146)	.199
Extension deficit, degrees	7 (0-15)	6 (0-15)	9 (3-15)	7 (0-10)	5 (0-10)	0 (0-5)	.093
Pronation, degrees	87 (85-90)	89 (85-90)	89 (85-90)	90 (86-90)	85 (82-86)*	90 (84-90)*	.302
Supination, degrees	89 (85-90)	90 (80-90)	87 (85-90)	90 (85-90)	85 (80-90)	88 (79-90)	.661
VAS	1 (0-3)	0 (0-1)	0 (0-1)	1 (0-2)	0 (0-1)	0 (0-2)	.185

VAS, visual analog scale; *IQR*, interquartile range.
Range of motion is corrected for age.
* Values are statistically significant differences at the corresponding follow-up moment.

In a retrospective study, Rineer et al[23] concluded that Mason type 2 fractures with at least 1 fracture fragment without cortical contact are 21 times more likely to be associated with a complex injury pattern, compared with fractures with cortical contact.

A systematic review by Kaas et al[16] in 2012, describing 9 retrospective case series including 224 patients with a Mason type 2 radial head fracture, found that nonoperative treatment was successful in 80% of patients and operative treatment in 93% of patients ($P = .01$). Successful treatment was defined as an excellent or good result according to the Broberg and Morrey score, MEPS, or Radin score. The authors concluded that no firm conclusions could be drawn because the included retrospective studies had a low level of evidence, small patient numbers, and a large heterogeneity in study design and results. Moreover, data regarding revision surgery or presence of complications was not reported.

Our results are comparable with previous data on the mid-term to long-term functional outcomes of Mason type 2 radial head fractures, with nonoperative treatment routinely providing a satisfactory outcome. A retrospective study conducted by Yoon et al[29] in which nonoperative treatment was compared with operative treatment in patients with a Mason type 2 radial head fracture with 2-5 mm displacement (mean follow-up of 3 and 4.5 years, respectively) found no clinical benefit of either treatment with mean QuickDASH scores of 7 (95% CI 2-11) and 6 (95% CI 4-10) ($P = .90$). The MEPS was even significantly better in the nonoperative group compared with the operative group (93, 95% CI 89-97, vs. 86, 95% CI 80-90; $P = .01$). In addition, besides a better pronation in the nonoperative group, range of motion of the elbow was comparable between both groups. Moreover, in a long-term follow-up study from a prospective database on 43 primarily nonoperatively treated Mason type 2 radial head fractures, Duckworth et al[11] found excellent patient-reported outcomes. At a mean of 10 years of follow-up, the mean DASH score was 6.1 (95% CI 2.5-9.7) and the mean OES was 45.5 (95% CI 44-47). Only 1 patient underwent open reduction and internal fixation at 10 days following trauma because of a persistent block to forearm rotation.

In the Netherlands, physiotherapy sessions are not included in the basic health insurance plans. Therefore, physiotherapy was at the discretion of the patients in our study. However, the patients who practiced with a physiotherapist were equally divided between both groups. Consequently, we do not consider physiotherapy to be a confounder in this study.

Concerning the degree of displacement, it has long been generally agreed, though not supported by any literature, that Mason type 2 fractures with displacement ≥2 mm are amenable to surgical fixation. Nonetheless, current research has shown that fracture displacement of 2 mm or even ≥3 mm is not necessarily an indication of poor outcome in nonoperatively treated radial head fractures.[12] Duckworth et al,[11] in 100 patients with a Mason type 1 or 2 radial head fracture, found a trend toward a significantly worse DASH score for patients whose fracture displacement was ≥4 mm compared with patients whose fracture displacement was <4 mm (mean DASH score 13.7 compared with 5.2; $P = .07$). However, they concluded that no firm conclusions could be drawn from the above finding because of the small sample size and the inevitable degree of intra- and interobserver variability associated with the measurement of fracture displacement. The only clear indication for surgery in isolated displaced partial articular radial head fractures, not associated with other fractures or ligament injuries, is mechanical block to forearm rotation.[10,11,20]

This trial has several limitations. First, because the treatment allocation involved a surgical procedure, assessment was not blinded. Covering the affected elbow could have kept the assessors blinded for only the range of motion measurements. However, our primary outcomes, the DASH score and the OES, were completed by the patient without involvement of the examiner, thus avoiding biased assessments of these outcomes. Second, the target sample size was not reached because of slow recruitment and a high number of crossovers from the operative group to the nonoperative group. These patients demanded nonoperative treatment because they had minor complaints of their affected elbow just before the scheduled surgery. Nonetheless, DASH scores at 12 months in the nonoperative group suggested equally good functional outcomes, leaving limited scope for improvement by operative treatment. The mean DASH score at 12 months was 7 in the operative group and 4 in the operative group. This mean difference of 3 is clinically irrelevant, because it is lower than the minimal clinically important difference (MCID).[27] Additionally, nonoperative treatment is also preferred from a commercial point of view, because the direct costs of operative treatment are not taken into account. Despite its early termination, to our knowledge the RAMBO trial is the first multicenter randomized study to date to compare operative with nonoperative treatment of isolated displaced partial articular radial head fractures.

Conclusion

Open reduction and screw fixation in adults with an isolated Mason type 2 radial head fracture is not superior to nonoperative treatment. Hence, we cannot support the use of open reduction and screw fixation for this type of injury. Despite the premature termination, this study adds evidence to the existing literature guiding the treatment of this common fracture.

Disclaimers

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Denise Eygendaal has done consulting work for Lima Corporates, has given paid presentations for the AO Foundation and Stryker, and received institutional support from Matthys, Zimmer-Biomet, and Stryker. In addition, a relative of Denise Eygendaal is a stakeholder for ITEC medical. All of the above-mentioned is not related to the subject of this work.

All the other authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jse.2021.02.025.

References

1. Aasheim T, Finsen V. The DASH and the QuickDASH instruments. Normative values in the general population in Norway. J Hand Surg Eur 2014;39:140-4. https://doi.org/10.1177/1753193413481302
2. Akesson T, Herbertsson P, Josefsson PO, Hasserius R, Besjakov J, Karlsson MK. Primary nonoperative treatment of moderately displaced two-part fractures of the radial head. J Bone Joint Surg Am 2006;88:1909-14. https://doi.org/10.2106/JBJS.E.01052

3. Broberg MA, Morrey BF. Results of delayed excision of the radial head after fracture. J Bone Joint Surg Am 1986;68:669-74.
4. Bruinsma W, Kodde I, De Muinck Keizer RJ, Kloen P, Lindenhovius A, Vroemen J, et al. A randomized controlled trial of nonoperative treatment versus open reduction and internal fixation for stable, displaced, partial articular fractures of the radial head: The RAMBO trial. BMC Musculoskelet Disord 2014;15:147. https://doi.org/10.1186/1471-2474-15-147
5. Burkhart KJ, Wegmann K, Müller LP, Gohlke FE. Fractures of the radial head. Hand Clin 2015;31:533-46. https://doi.org/10.1016/j.hcl.2015.06.003
6. Conover WJ, Iman RL. Analysis of covariance using the rank transformation. Biometrics 1982;38:715.
7. Cusick MC, Bonnaig NS, Azar FM, Mauck BM, Smith RA, Throckmorton TW. Accuracy and reliability of the Mayo Elbow Performance Score. J Hand Surg Am 2014;39:1146-50. https://doi.org/10.1016/j.jhsa.2014.01.041
8. Dawson J, Doll H, Boller I, Fitzpatrick R, Little C, Rees J, et al. The development and validation of a patient-reported questionnaire to assess outcomes of elbow surgery. J Bone Joint Surg Br 2008;90:466-73. https://doi.org/10.1302/0301-620X.90B4.20290
9. De Muinck Keizer RJO, Walenkamp MMJ, Goslings JC, Schep NWL. Mason type I fractures of the radial head. Orthopedics 2015;38:e1147-54. https://doi.org/10.3928/01477447-20151123-06
10. Duckworth AD, Watson BS, Will EM, Petrisor BA, Walmsley PJ, Court-Brown CM, et al. Radial head and neck fractures: functional results and predictors of outcome. J Trauma 2011;71:643-8. https://doi.org/10.1097/TA.0b013e3181f8fa5f
11. Duckworth AD, Wickramasinghe NR, Clement ND, Court-Brown CM, McQueen MM. Long-term outcomes of isolated stable radial head fractures. J Bone Joint Surg Am 2014;96:1716-23. https://doi.org/10.2106/JBJS.M.01354
12. Furey MJ, Sheps DM, White NJ, Hildebrand KA. A retrospective cohort study of displaced segmental radial head fractures: is 2 mm of articular displacement an indication for surgery? J Shoulder Elbow Surg 2013;22:636-41. https://doi.org/10.1016/j.jse.2013.01.019
13. Grewal R, MacDermid JC, Faber KJ, Drosdowech DS, King GJW. Comminuted radial head fractures treated with a modular metallic radial head arthroplasty: study of outcomes. J Bone Joint Surg Am 2006;88:2192-200. https://doi.org/10.2106/JBJS.E.00962
14. Hudak PL, Amadio PC, Bombardier C. Development of an upper extremity outcome measure: the DASH (Disabilities of the Arm, Shoulder and Hand). The Upper Extremity Collaborative Group (UECG). Am J Ind Med 1996;29:602-8.
15. Hunsaker FG, Cioffi DA, Amadio PC, Wright JG, Caughlin B. The American Academy of Orthopaedic Surgeons outcomes instruments: normative values from the general population. J Bone Joint Surg Am 2002;84:208-15. https://doi.org/10.2106/00004623-200202000-00007
16. Kaas L, Struijs PA, Ring D, van Dijk CN, Eygendaal D. Treatment of Mason type II radial head fractures without associated fractures or elbow dislocation: a systematic review. J Hand Surg Am 2012;37:1416-21. https://doi.org/10.1016/j.jhsa.2012.03.042
17. Kaas L, van Riet RP, Vroemen JPAM, Eygendaal D. The epidemiology of radial head fractures. J Shoulder Elbow Surg 2010;19:520-3. https://doi.org/10.1016/j.jse.2009.10.015
18. Kahan BC, Morris TP. Reporting and analysis of trials using stratified randomisation in leading medical journals: review and reanalysis. BMJ 2012;345:e5840. https://doi.org/10.1136/bmj.e5840
19. Khalfayan EE, Culp RW, Alexander AH. Mason type II radial head fractures: operative versus nonoperative treatment. J Orthop Trauma 1992;6:283-9.
20. Lindenhovius ALC, Felsch Q, Ring D, Kloen P. The long-term outcome of open reduction and internal fixation of stable displaced isolated partial articular fractures of the radial head. J Trauma 2009;67:143-6. https://doi.org/10.1097/TA.0b013e31818234d6
21. Mason ML. Some observations on fractures of the head of the radius with a review of one hundred cases. Br J Surg 1954;42:123-32.
22. Pearce MS, Gallannaugh SC. Mason type II radial head fractures fixed with Herbert bone screws. J R Soc Med 1996;89:340P-4P.
23. Rineer CA, Guitton TG, Ring D. Radial head fractures: loss of cortical contact is associated with concomitant fracture or dislocation. J Shoulder Elbow Surg 2010;19:21-5. https://doi.org/10.1016/j.jse.2009.05.015
24. Ring D. Displaced, unstable fractures of the radial head: fixation vs. replacement—what is the evidence? Injury 2008;39:1329-37. https://doi.org/10.1016/j.injury.2008.04.011
25. Ring D, Quintero J, Jupiter JB. Open reduction and internal fixation of fractures of the radial head. J Bone Joint Surg Am 2002;84:1811-5. https://doi.org/10.2106/00004623-200210000-00011
26. Smith MV, Klein SE, Clohisy JC, Baca GR, Brophy RH, Wright RW. Lower extremity-specific measures of disability and outcomes in orthopaedic surgery. J Bone Joint Surg Am 2012;94:468-77. https://doi.org/10.2106/JBJS.J.01822
27. Sorensen AA, Howard D, Tan WH, Ketchersid J, Calfee RP. Minimal clinically important differences of 3 patient-rated outcomes instruments. J Hand Surg Am 2013;38:641-9. https://doi.org/10.1016/j.jhsa.2012.12.032
28. Struijs PAA, Smit G, Steller EP. Radial head fractures: effectiveness of conservative treatment versus surgical intervention. Arch Orthop Trauma Surg 2007;127:125-30. https://doi.org/10.1007/s00402-006-0240-4
29. Yoon A, King GJW, Grewal R. Is ORIF superior to nonoperative treatment in isolated displaced partial articular fractures of the radial head? Clin Orthop Relat Res 2014;472:2105-12. https://doi.org/10.1007/s11999-014-3541-x